**Draft Internal Assessment Resource**
**For planning purposes only**



**Draft standard Physics 2.5**: Demonstrate understanding of atomic and nuclear physics

**Resource reference:** Physics 2.5A

**Resource title:** Models of the Atom

**Credits:** 3

## Teacher guidelines

The following guidelines are designed to ensure that teachers can carry out valid and consistent assessment using this internal assessment resource.

Teachers need to be very familiar with the outcome being assessed by Achievement Standard Physics 2.5. The achievement criteria and the explanatory notes contain information, definitions, and requirements that are crucial when interpreting the standard and assessing students against it.

## Context/setting

Because of the detailed evidence given in the schedule, the particular context for which this activity has been written cannot be used for assessing the standard. A different context must be chosen and the task adapted.

This assessment activity requires students to conduct research on the model of the atom using secondary sources. Students will prepare three reports describing different implications of our understanding of the atom. The context of the first report is the development of historical models of the atom. The context of the second report is the Chernobyl accident and the mechanisms and health impacts of atomic radiation. The context of the third report is energy generation from nuclear fission or fusion.

## Conditions

This assessment activity will require multiple sessions. The report could be in one or more of the following formats:

- written report (including illustrations, diagrams and graphs, if appropriate)
- poster presentation (including annotations or supporting notes)
- oral presentation
- computer-assisted presentation
- wiki
- website.

Confirm the timeframe and presentation format(s) with your students.

All sources of information, images, diagrams (not generated by the student) and data must be acknowledged. All sources of information must be recorded in a traceable format which means that someone else could go straight to where the information came from.

## Resource requirements

Ensure students have access to a range of secondary information sources, for example, science magazines, science web sites, or reference books, or provide the information directly.

## Additional information

The Chernobyl New Zealand Herald article can be found at: http://www.nzherald.co.nz/nuclear-power/news/article.cfm?c_id=500837&objectid=10641227.

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| Achievement | Achievement with Merit | Achievement with Excellence |
|---|---|---|
| Demonstrate understanding of atomic and nuclear physics. | Demonstrate in-depth understanding of atomic and nuclear physics. | Demonstrate comprehensive understanding of atomic and nuclear physics. |



## Student instructions

### Introduction

Our understanding of the physical world has increased at an incredible rate in the last 200 years. The key to the advances made in physics has been our growing knowledge about atoms. In 1897, J. J. Thomson carried out an experiment that led to the discovery of the electron and used this to create a new model of the atom. Thomson's model of the atom was then revised as a result of the gold foil experiment carried out by the New Zealander Ernest Rutherford and his assistants, Geiger and Marsden. Rutherford's model was later replaced by the Bohr model. Researchers continue to refine our understanding of the atom, and its implications.

We have used this understanding to develop new sources of energy, for example nuclear fission reactors. Nuclear energy has tremendous potential, but it can also be dangerous. Radioactive emissions increase the likelihood of developing cancer. *"In 2010, Ukraine's President warned that, on the 24th anniversary of the world's worst atomic accident, the Chernobyl nuclear reactor* ***remains a serious threat*** *to Europe. The 1986 reactor explosion sent a* ***cloud of radiation*** *over much of the continent and severe health problems persist. President Viktor Yanukovych says around two million people have illnesses caused by the radiation, and non-governmental organisations estimate the disaster has caused more than 700,000 early deaths. The reactor is encased in a deteriorating shell and internationally funded work to replace it is far behind schedule."* (New Zealand Herald 2010)

Despite setbacks such as the Chernobyl reactor accident, many people believe that nuclear reactors remain an effective way of delivering electricity in a world increasingly worried about carbon emissions. For example, "*Microsoft founder Bill Gates and Japan's Toshiba will team up to develop a next-generation* ***fission*** *nuclear reactor that can run for up to 100 years without refuelling, a 2010 report said. Their joint development efforts would focus on the Travelling-Wave Reactor (TWR), which uses depleted uranium as fuel for fission."* (NZ Herald 2010) and "*Russia and Italy have signed a memorandum on intentions regarding cooperation in the construction of an experimental thermonuclear* ***fusion*** *reactor. The two countries are currently involved in the construction of an experimental thermonuclear reactor on Russian territory using experts from both countries. The reactor is the latest development in the tokamak family of thermonuclear power-generating reactors." (*ITAR-TASS news agency 2010)

Both fission and fusion reaction are capable of creating **large amounts of energy**, especially when compared to chemical reactions such as burning fossil fuels. The key to understanding this release of energy is the equation $\mathbf{E = mc^2}$ proposed by Albert Einstein.

## Task



In this assessment, you will review secondary information about three different atomic contexts: early atomic model experiments, the Chernobyl accident, and modern nuclear power plants. You will prepare a report for each context describing aspects of our understanding of the atom. Agree with your teacher on the format(s) of your reports page. Formats could be a written report, poster presentation, oral presentation, computer-assisted presentation, wiki or website presentation.

### *Part 1*

Write a short report illustrating how our understanding of the atom advanced from Thomson's model of the atom to Rutherford's model of the atom. Your report should:

- provide a comprehensive description of the experiment Thomson used to discover the electron
- explain in detail how this experiment led Thomson to develop his model of the atom
- provide a comprehensive description of the gold foil experiment that Rutherford and his associates used to further investigate the structure of the atom
- explain in detail how the findings of the gold foil experiment were incorporated in the Rutherford model of the atom
- describe the limitations of Rutherford's model of the atom
- explain why these limitations implied further research was required.

Your report should demonstrate understanding of the links between the experiments and the underlying concepts, for example, by giving reasons for the observations in terms of physics principles and making connections between the model of the atom, experimental findings and these physics principles.

### *Part 2*

Write a short report illustrating the dangers of radioactivity, explaining why the Chernobyl reactor accident was dangerous when it occurred 25 years ago, and why it is still regarded as dangerous today. Your report should:

- define and describe the physics of three main types of nuclear radiation – alpha radiation, beta radiation, and gamma radiation
- discuss each type of radiation in terms of its relative ionising and penetrating ability
- provide a comprehensive explanation of why the "cloud of radiation" was dangerous to humans
- provide a comprehensive explanation of why the "nuclear reactor remains a serious threat to Europe" nearly 25 years after the accident occurred – your explanation should consider the half life of radioactive materials (exact values of half life or radioactive isotopes are not required).

Your report should demonstrate understanding of the links between the harmful effects of the accident and the underlying physics concepts, for example, by making connections between the products of nuclear fission and why radiation can be dangerous to humans.

### *Part 3*

Write a short report illustrating why nuclear power is still considered to be an effective way of producing electricity. Your report should:

- provide a comprehensive description of a typical fission reaction that occurs in a nuclear fission reactor (details of the reactor itself are not required)
- provide a comprehensive description of a typical fusion reaction that occurs in a nuclear fusion reactor (details of the reactor itself are not required)
- explain in detail how the equation E = mc 2, applied to the physics of fission and fusion, justifies why nuclear power is worth considering as a source of energy, for example, by comparing the outputs of fossil fuel and nuclear power plants.

Your report should demonstrate understanding of the links between nuclear power plants and the underlying physics concepts, for example, by making connections between fusion reactions and Einstein's equation.



 

## Assessment schedule: Physics 2.5A Models of the Atom

| Evidence/Judgements for Achievement | Evidence/Judgements for Achievement with Merit | Evidence/Judgements for Achievement with Excellence |
|---|---|---|
| Reports describe:<br>• the Thomson and Rutherford models of the structure of the atom<br>• a limitation of each model<br>• the danger of radioactivity in terms of alpha, beta, gamma radiation and radioactive half-life<br>• a typical fission reaction<br>• a typical fusion reaction<br>• how $E = mc^2$ relates to the conversion of matter into energy.<br><br>For example a student might provide the following information:<br>• Thomson applied high voltages across gases in tubes to produce a stream of particles that were attracted to the positive charge<br>• diagram or description of the gold-leaf experiment<br>• Rutherford's model does not explain why the electrons are in a stable orbit<br>• alpha have low penetrating power and high ionising effect<br>• beta have medium penetrating power and medium ionising effect<br>• gamma have very high penetrating power and low ionising effect<br>• radioactive material has a half-life – the time it takes to lose half of its radioactivity | Reports demonstrates in depth understanding, giving reasons for what occurred in terms of the physics principles involved:<br>• why the Thomson and Rutherford experiments required scientists to revise models of the atom<br>• why each model had limitations<br>• the relationship between the physics of alpha, beta, and gamma particles and their danger<br>• the relative energy of a fission reaction<br>• the relative energy of a typical fusion reaction<br>• why nuclear power is worth considering as a source of energy.<br><br>For example a student might provide the following information:<br>• Thomson's particles were negatively charged electrons and had to originate from inside the atom<br>• the majority of Rutherford's alpha particles travelled through the foil undeflected, so the majority of the volume of an atom must be empty space<br>• accelerating charges (electrons) emit electromagnetic energy (lose energy) and should eventually crash into the nucleus/electrons should produce a rainbow spectrum<br>• alpha particles are relatively **slow** and **heavy** – they are not very penetrating so cannot travel far in air and cannot pass through skin (but they | Reports demonstrates comprehensive understanding of the models of the structure of the atom, giving reasons for what occurred in terms of the physics principles involved, and also making connections between models of the atom, experimental findings, and physics principles. Report explains:<br>• how the Thomson and Rutherford experiments implied particular structural features of the atom<br>• relative volumes of electron cloud and nucleus of the atom<br>• how the limitations of the Rutherford model indicated areas for further research<br>• relative danger of alpha, beta, and gamma particles and how human tissue was most likely to encounter each type of particle following Chernobyl<br>• an estimate of how long the by-products of nuclear power will be dangerous<br>• the energy and relative pollution of nuclear reactions compared with fossil fuels.<br><br>For example a student might provide the following information:<br>• Thomson's electrons must be negatively charged, but since the atom is neutral overall, there must be positive charges in the nucleus to balance out the negative charges<br>• the nucleus is only a very small part of the atom's volume because the majority of the alpha particles travelled through the foil undeflected, |

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| • all radioactive material eventually decays into non-radioactive elements<br>• a typical fission reaction in a nuclear reactor involves a large atom splitting into two smaller daughters products e.g.<br>• ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{142}_{56}Ba + {}^{91}_{36}Kr + 3\,{}^{1}_{0}n$<br>• a typical fusion reaction in a t*okamak* involves two small atoms joining to make one larger atom as a product e.g.<br>• ${}^{3}_{1}H + {}^{2}_{1}H \rightarrow {}^{1}_{0}n + {}^{4}_{2}He$<br>• $E = mc^2$ defines the relative quantities in the conversion of matter to energy (and vice versa)<br>• E represents energy, m mass and c is the speed of light. | may damage the skin in the process)<br>• alpha particles are strong ionisers and would ionise the contents of cells in human bodies<br>• beta particles are faster than alpha and lighter in terms of mass so can travel further in air and can penetrate skin but cannot penetrate through human tissues/the whole body<br>• beta particles are ionisers and might ionise the contents of cells in human bodies<br>• gamma rays travel very quickly, can penetrate skin, but cannot penetrate through most things<br>• gamma rays are weak ionisers and are unlikely to ionise the contents of cells in human bodies<br>• some radioactive material has a long half life<br>• a typical fission reaction allows produces a lot of thermal energy as a product of the reaction, for example, 200 MeV of energy for each fission event of: ${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{142}_{56}Ba + {}^{91}_{36}Kr + 3\,{}^{1}_{0}n$<br>• a typical fusion reaction allows produces a lot of thermal energy as a product of the reaction, for example, 3.5 MeV for each fusion event for<br>• ${}^{3}_{1}H + {}^{2}_{1}H \rightarrow {}^{1}_{0}n + {}^{4}_{2}He$<br>• $E = mc^2$ explains how converting mass to energy can produce large amounts of energy. | but the mass of the nucleus must be relatively large (as electrons have very small mass)<br>• Rutherford's model doesn't explain why electron orbits are stable/electrons should produce a rainbow spectrum and therefore electron arrangement inside atoms needs to be further explained<br>• alpha and beta are charged particles that can ionise the contents of human cells causing (amongst other things) cancer if they deposit energy in sensitive tissue<br>• alpha are not very penetrating so would not be very harmful unless a source of alpha particles were inhaled, but because there was a cloud of radioactivity it is likely that sources of alpha radiation would be inhaled<br>• because they have a large charge, alpha particles ionise other atoms strongly<br>• beta travels further in the body than alpha, interacting with more tissue<br>• gamma rays are very difficult to stop (you require lead or concrete shielding to keep you safe from them), but gamma rays do not directly ionise other atoms, although they may cause atoms to emit other particles which will then cause ionisation<br>• because some of the radioactive material at Chernobyl has a long half life, this material will remain hazardous to humans for a long time<br>• as explained by $E = mc^2$, typical fission and fusion reactions produce orders of magnitude more thermal energy as a product of the reaction than a chemical reaction and produce no carbon emissions. |



Final grades will be decided using professional judgement based on a holistic examination of the evidence provided against the criteria in the Achievement Standard.